

Stack Measurement on StarCore™-Based DSPs

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Stack allocation can be a very delicate problem in a real-time application for embedded systems. Because of the scarcity of memory space, it is desirable to allocate as little stack space as possible while still covering the worst-case stack needs.

However, it can be difficult to define with accuracy the amount of stack space needed in the worst case of a complex application. Interrupts are a further complication. Therefore, it is usually more practical to measure stack usage during testing and determine the maximum space requirements. Of course, it is up to the testing engineer to select adequate test vectors that approach the worst case. This application note presents two ways to measure stack usage for applications running on the StarCore™ SC140/SC1400 DSP core:

- *Add extra code to the application for monitoring the stack.* This method is a little more complex since it requires additional code in the program. Also, it must be used with caution to avoid problems covered in the guidelines section of this document. However, the measurements can be performed directly on the chip and are much faster.
- *Run the program with a simulator and monitor the stack pointer.* This method requires no code modifications. Someone with no access to the source can perform the measurements. This method always pinpoints the top of the stack without errors. Also, it can provide the stack trace for the worst case, which is valuable information when the goal is to decrease stack size. However, since this method runs on the simulator, it is much slower than the first method and may be unusable for a complex application. One solution is to add extra code to the application to locate the frame where the maximum stack occurs and run the simulator only on that frame to obtain more detailed information.

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1 Stack Measurement From A Program

This section presents the watermarking method of stack measurement along with an example implementation to run on the SC140 core. Watermarking fills the stack with a known value (the search pattern) before the function executes and then determines how much of the pattern is overwritten. The highest address of a stack position containing a value that differs from the search pattern defines the maximum value of the stack top required for execution of the function. The watermarking method is similar to measuring the maximum water level in a river; the water leaves a mark on a special marker that remains after the water level drops (see **Figure 1**).

The tested function may duplicate the search pattern on the stack during its execution, but it is unlikely if the value of the search pattern is chosen properly. The pattern must be a value with a low probability of appearing randomly on the stack, and it can depend on the application (for example, 0 is probably not a good choice, since it often appears on the stack). The final verification of the stack is top-down to ensure against finding a fake stack top. Even if the application never writes the value of the pattern on the stack, a function may still allocate space for local variables or even vectors and leave some of them unchanged for a certain execution.

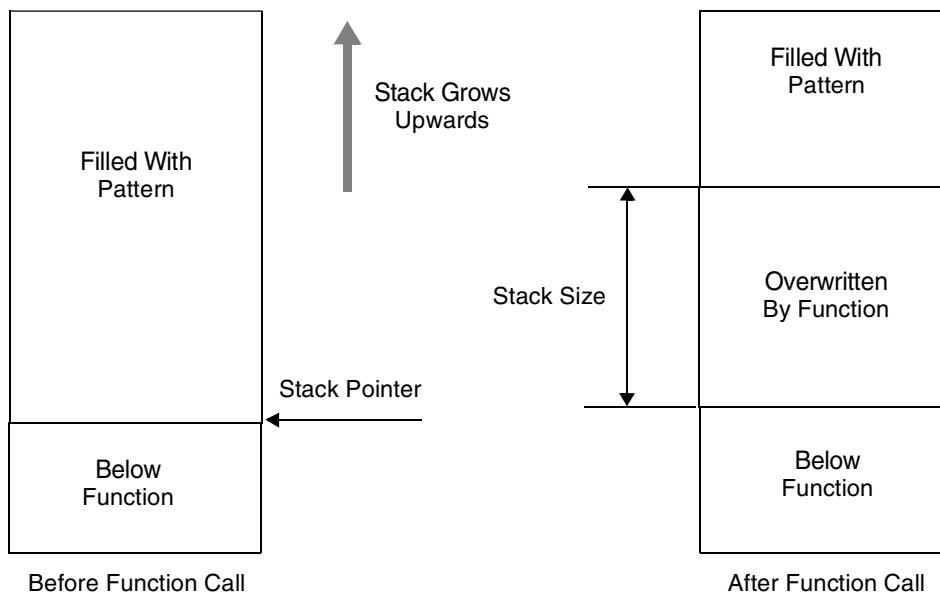


Figure 1. Measuring the Stack by Watermarking

1.1 Implementation

Example 1 shows a proposed application programming interface (API) for measuring stack usage. The library code is written in assembly and optimized for speed.

Example 1. Proposed API for Stack Measurement, MDCR_SC100_Stack.h

```
#ifndef __MDCR_SC100_STACK_H
#define __MDCR_SC100_STACK_H

void * MDCR_SC100_GetSP(void);
void * MDCR_SC100_MarkStack(void);
unsigned int MDCR_SC100_GetStack(void);

#endif
```

This is the header file containing the declarations of the three functions. The definitions are listed in **Example 2**, **Example 3**, and **Example 4**. The `_MDCR_SC100_GetSP()` function returns the value of the stack pointer before the call.

Example 2. ASM Code for Stack Measurement, `_MDCR_SC100_GetSP`

```
GLOBAL _MDCR_SC100_GetSP
    ALIGN 16
    _MDCR_SC100_GetSP TYPE FUNC
        rts             adda #<-8,sp,r0          ; -8 for
        return address
        GLOBAL F_MDCR_SC100_GetSP_end
        F_MDCR_SC100_GetSP_end
        SIZE _MDCR_SC100_GetSP,*-_MDCR_SC100_GetSP
```

The `MDCR_SC100_MarkStack()` function in **Example 3** fills the stack with the search pattern. It starts from the current stack pointer and stops at the `_MDCR_SC100_TopOfStack` marker, which represents the top of the currently allocated stack space and must be a multiple of 8. This function must be called just before the call to the tested function. It returns the current stack pointer, which represents the stack base for the tested function (see **Figure 2**).

Example 3. ASM Code for Stack Measurement, `_MDCR_SC100_MarkStack`

```
GLOBAL _MDCR_SC100_MarkStack
    ALIGN 16
    _MDCR_SC100_MarkStack TYPE FUNC
        tfra sp,r1      adda #<8,sp,r0          ; second write pointer
        move.l r1,d0     move.l #<_MDCR_SC100_TopOfStack,d1
        [
            sub d0,d1,d0   move.w #<2,n0           ; d0 is size of stack
        ]
        [
            asrr #<4,d0      ; loop executes
            stack_size/16 times
            bmtsts #<8,d0.1   move.l #<8,d0.1         ; assuming d0 is a
            multiple of 8       ; this is false if d0 is
        ]
        a
        [
            doensh3 d0         ; multiple of 16
            move.l MDCR,d2
            tfr d2,d3
        LOOPSTART3
            move.2l d2:d3,(r1)+n0 move.2l d2:d3,(r0)+n0 ; write 16 bytes at a
            time
        LOOPEND3
            rtsd             adda #<-8,sp,r0          ; return stack base in r0
            ift move.2l d2:d3,(r1)                         ; if size of stack is not
        a
            ; multiple of 16 write 8
        more bytes
        GLOBAL F_MDCR_SC100_MarkStack_end
        F_MDCR_SC100_MarkStack_end
        SIZE _MDCR_SC100_MarkStack,*-_MDCR_SC100_MarkStack
```

Figure 2 shows the stack layout after execution of `MDCR_SC100_MarkStack`. The `_StackStart`, `_MDCR_SC100_TopOfStack` and `_TopOfStack` symbols are all defined in the linker command file (.cmd).

Stack Measurement From A Program

_StackStart and _TopOfStack represent the boundaries of the memory space allocated for stack and heap.

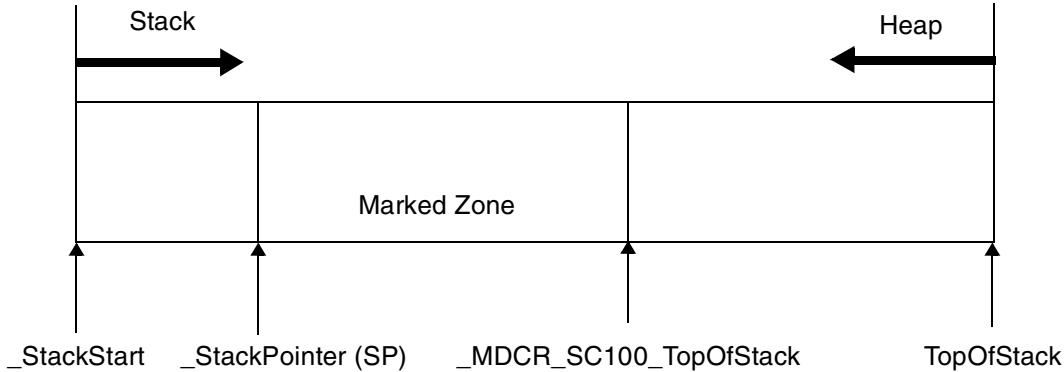


Figure 2. Stack Layout After Marking

The `MDCR_SC100_GetStack()` function in **Example 4** must be called after the tested function has returned. It inspects the stack from top down to find the highest modified location, and it returns the size of the stack, measured from the current stack pointer (that is, the value of `SP` before the function call). If the last eight bytes of the stack are modified, the function returns a value of `-1` to indicate stack overflow. The initial stack allocation is insufficient, and the tester should allocate more stack and try again. For the measurement to be correct, the stack pointer must have the same value before the call to `MDCR_SC100_MarkStack` and before the call to `MDCR_SC100_GetStack`. If for some reason this cannot happen, `MDCR_SC100_GetSP` is used to return the current `SP`. Then the size of the stack is `MDCR_SC100_GetStack() + MDCR_SC100_GetSP() - base`, where `base` is the return value of `MDCR_SC100_MarkStack()` or any other value you chose as stack base.

Example 4. ASM Code for Stack Measurement, `_MDCR_SC100_GetStack`

```
GLOBAL _MDCR_SC100_GetStack
    ALIGN 16
    _MDCR_SC100_GetStack TYPE FUNC
        move.l #<(_MDCR_SC100_TopOfStack-4),r0
        adda #<-28,sp,r1
                                ; 8 for return address
                                ; 16 for extra reads from
(r0)
        move.l (r0)-,d1
        [
            cmpeq d2,d1
            move.l (r0)-,d1
        ]
        [
            move.l Pattern,d2
                                ; check top of stack
        ]
        [
            IFT
            cmpeq d2,d1
                                ; check next element
        ]
        move.l #-1,d0
        [
            IFF
            rts
                                ; stack overflow: return
-1
            IFT
        ]
    
```

```

        move.l (r0)-,d1
    ]
FALIGN
L0_0
[
    cmpeq d2,d1
    btd L0_0
]
move.l (r0)-,d1
    suba r1,r0
    move.l r0,d0
    and d1,d0
multiple of 8
    GLOBAL F_MDCR_SC100_GetStack_end
F_MDCR_SC100_GetStack_end
    SIZE _MDCR_SC100_GetStack,*-_MDCR_SC100_GetStack

```

1.2 Guidelines

For the MDCR_SC100_GetStack function, stack overflow is indicated by the modification of the last valid position in stack (last eight bytes). However, if those bytes are not modified, this does *not* guarantee the absence of a stack overflow. A function can allocate a certain amount of stack space and not write all of it (leave “holes” on the stack still containing the search pattern). Then the function can write beyond the top stack marker, leaving the top of the stack untouched. To avoid such problems, establish a certain safety value greater than any stack gap that can appear, depending on the application. When the remaining space on the stack is smaller than this value, treat this as a possible overflow and allocate more memory for the stack by increasing the MDCR_SC100_TopOfStack marker. The remaining space on the stack can be calculated as MDCR_SC100_TopOfStack - MDCR_SC100_GetSP() - MDCR_SC100_GetStack().

If the application allocates memory dynamically, extra attention must be paid to the size of the heap. The heap can grow beyond the MDCR_SC100_TopOfStack marker, and MDCR_SC100_GetStack() reports this as a stack overflow. Of course, increasing MDCR_SC100_TopOfStack only makes the problem worse since it leaves even less space for the heap. The solution here is to increase stack and heap size by changing the memory allocation in the linker command file (increase _TopOfStack - _StackStart).

Interrupts should be disabled when the tested function executes so that they do not influence the results in unpredictable ways. To measure the worst stack case for the application that includes interrupts, measure the stack space for interrupt handling routines separately, since it is usually impossible to trigger the interrupts exactly when the function stack reaches its maximum size.

1.3 Example of Library Use

Example 5 shows how to use the previously-discussed functions to measure the stack size for a function.

Example 5. Stack Size for a Function, stack_measurement.c

```

#include <stdio.h>
#include "mdcr_sc100_stack.h"

int function3(int n)
{
    #pragma noinline
    int v[10];
    int i;

```

```

v[0] = v[1] = 1;
for (i=2; i<10; i++)
{
    v[i] = v[i-1] + v[i-2];
}
return v[n];
}

int function2(int n)
{
#pragma noinline
    if (n==1) return 1;
    else return function3(n);
}

int function1(int n)
{
#pragma noinline
    if (n<=0) return 0;
    else return function2(n);
}

void main()
{
    int n=0;
    int i;
    int stack_size;

    for (i=0; i<3; i++)
    {
        MDCR_SC100_MarkStack();
        n+=function1(i);
        stack_size = MDCR_SC100_GetStack();
        printf ("\nStack size for call %d: %d\n", i, stack_size);
    }
}

```

This program was compiled with Metrowerks® StarCore C compiler R 1.1 with –O3 optimization option, and the output is as shown in **Example 6**.

Example 6. Test Program Output

```

Stack size for call 0: 8
Stack size for call 1: 16
Stack size for call 2: 64

```

2 Stack Measurement With a Simulator

Measuring the stack from an application running on the hardware is much faster than measuring the stack from a simulator. However, the simulator offers some advantages. It does not require the addition of code to the program, and it yields more detailed information. This method of stack measurement is precise. It indicates the exact value of the stack in any moment, not just the maximum value. It is not influenced by overflows or by the heap overwriting the stack, unless the application crashes. Measuring the stack on a simulator, we can monitor all changes of the stack pointer. The value of the stack pointer before the call to the function (or the value after the call to the function minus eight) is the base of the stack. The maximum of all the different stack pointer values between the beginning and the end of the function represents the top of the stack. Subtracting the stack base from this value

yields the stack usage for that execution of the function. We locate the beginning of the function by setting a breakpoint to that function. The problem is finding the end. Since compilers do not usually generate labels for the last instruction of a function, it is hard to set a breakpoint there. If the simulator offers more advanced options, such as stepping out from a function, the problem is easily solved. Otherwise, a call to an empty function must be inserted immediately after the call to the tested function and the breakpoint set on the empty function call. If a call to another function already exists at that location, it can be used instead.

2.1 SIMSC100 Simulator

We monitored the stack via the SIMSC100 simulator using a Perl script and a few SIMSC100 scripts. **Appendix A, Listing of Perl and simsc100 Scripts**, on page 11 presents a full listing of the scripts. The Perl script receives as parameters the name of the analyzed program (without the .eld extension) and the name of the function with an optional number of frames, which is the number of function calls after which the simulation stops. If the program does not call the function this many times, the simulation stops at the end of the program. The executable `program_name.eld` and the map file `program_name.map` must be in the current directory (the `.map` file is needed for the stack trace). It generates an output `.txt` file containing the maximum size of the stack and the stack trace for that execution of the function (`stack_analysis_program.txt`, where `program` stands for the name of the analyzed program) and another file containing the evolution of the stack for the frame that produced the largest stack (`stack_trace_program.txt`).

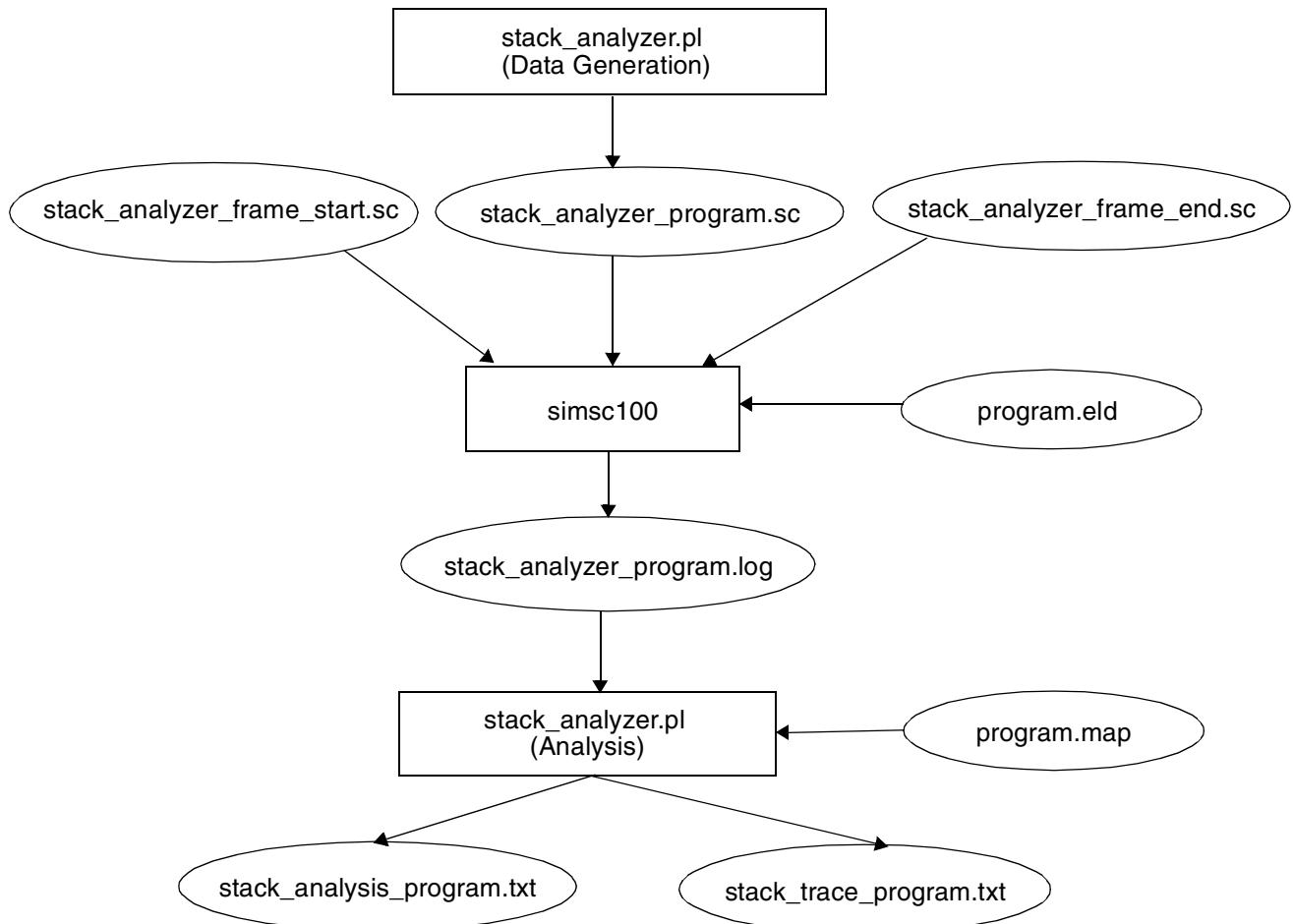


Figure 3. Measuring the Stack With the simsc100 Simulator

From the command line parameters the Perl script generates a SIMSC100 script (`stack_analyzer_program.sc`) and runs SIMSC100 using this script. The simulator generates a trace file from which the Perl script can later retrieve the necessary information. `stack_analyzer_program.sc` sets a breakpoint at the function entry to detect the beginning of the function and trigger the execution of another script (`stack_analyzer_frame_start.sc`). This script reads the stack pointer (`esp`) in the `cnt2` variable and sets a conditional breakpoint with the condition `esp < cnt2` to detect the end of the function and trigger the execution of the `stack_analyzer_frame_end.sc` script. Another breakpoint in `stack_analyzer_program.sc` prints the value of `esp` each time it changes but does not stop the simulation. This breakpoint is enabled when the function begins and disabled when it ends, so it prints only the values of `esp` inside the function. To count the function calls, a breakpoint at the function entry increments the `cnt1` counter, and another breakpoint stops the simulation when the counter reaches the required number. A breakpoint set at the end of program handles the case when the number of frames is too big or no number is specified.

When the simulator finishes the Perl script begins the analysis stage, using the generated trace file (`stack_analyzer_program.log`). The `program.map` file is read and the (`address, function_name`) pairs are recorded in a hash table. The log file is parsed by the Perl script and the maximum stack size is found. Finally the stack trace is generated by parsing the log file from the position where the maximum stack size was found, recording all the program locations where the stack pointer is decremented and looking up the corresponding function name in the hash table.

The script also generates a file (`stack_trace_program_name.txt`) containing the evolution of the stack for the frame that produced the largest stack, one (`function_name, stack_size`) pair per line. From this file a graph can easily be generated to summarize the evolution of the stack for that frame. Depending on the needs of the application developer, the scripts can be modified to produce other useful information.

2.2 Constraints

In addition to the fact that stack measurements on the simulator are significantly slower than those taken on the hardware platform, there are certain other constraints to keep in mind:

- Stack trace generation does not work for static functions since they do not appear in the `.map` file. Every static function that should appear in the stack trace is replaced by the name of the first global function that precedes it in memory.
- The `stack_analyzer_program.sc` script does not perform correctly in a multiprocess system. If a task switch occurs during the execution of the analyzed function, the results are totally corrupted.

2.3 Example of Script Use

Example 7 demonstrates the use of the `stack_analyzer_program.sc` script on a test program:

Example 7. Test Program for Stack Measurement Scripts

```
#include <stdio.h>

int function3(int n)
{
    #pragma noinline
    int v[10];
    int i;
```

```

v[0] = v[1] = 1;
for (i=2; i<10; i++)
{
    v[i] = v[i-1] + v[i-2];
}
return v[n];
}

int function2(int n)
{
#pragma noinline
    if (n<=1) return 1;
    else return function3(n) + function3(n-2);
}
int function1(int n)
{
#pragma noinline
    if (n<=0) return 0;
    else return function2(n) + function2(n-1);
}

int main()
{
    int n=0;
    int i;

    for (i=0; i<5; i++)
        n+=function1(i);

    return n;
}

```

The program name is `stack_test.c`. If we compile it with the following, we obtain the files `stack_test.map` and `stack_test.eld`:

```
scc -be -dm stack_test.map -o stack_test.eld stack_test.c
```

Next, we run the following script:

```
perl stack_analyzer.pl stack_test function1
```

and we obtain the file `stack_analysis_stack_test.txt` containing the maximum stack size and the stack trace listed from top to bottom:

Example 8. Script Output

```
Statistics made for stack_test :
```

```
Maximum stack size for function1 is 88 (in frame 3) with the following
call stack:
function3
function2
function1
```

The graph shown in **Figure 4** is generated from the resulting trace file (`stack_trace_stack_test.txt`). It represents the evolution of the stack for the frame that produces the largest stack.

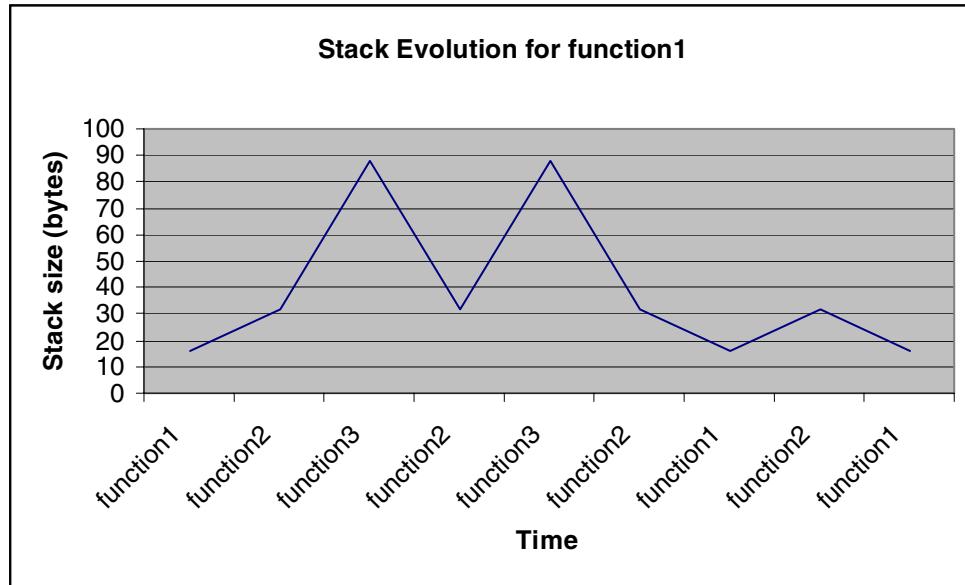


Figure 4. Stack Evolution for Example Program

3 References

- [1] Michael T. Trade. *Dynamic Stack Depth Determination Using ‘Footprint’ Analysis*.
- [2] *SCI40 DSP Core Reference Manual* (MNSC140CORE).
- [3] *SC100 C Compiler User’s Manual*, (MNSC100CC).
- [4] *SC100 Assembly Language Tools User’s Manual* (MNSC100ALT).
- [5] *SC100 Application Binary Interface Reference Manual* (MNSC100ABI).

Appendix A Listing of Perl and simsc100 Scripts

Following is the full listing of the scripts used for stack measurements in **Section 2, Stack Measurement With a Simulator:**

Example 9. stack_analyzer.pl

```
use warnings;
use strict;

# Receives as parameter a scalar that represents the name of the module
# being tested
# Returns a reference to a hash table containing the functions from the
# module received as
# parameter and with their addresses as keys
sub get_map_table
{
    my $module = shift; # Get the first parameter
    my %map_table;      # This is the map table that will be filled in
    this function
    my $fin;            # Map file descriptor
    # Open map file
    open( $fin , $module . ".map" ) || die("open " . $module . ".map" .
    ": $!\n");
    # Process the whole map file
    while( <$fin> )
    {
        # Match lines that contain a function name and its address
        # Such lines look like the one below:
        # 0x00013760           _Syn_filt
        # 0x00013850           _Weight_Az
        # 0x00013b60           _ACELP_Code_A
        if( /^(0x[0-9a-fA-F]{8})\s+_(\w+)\s*$/ )
        {
            # Hash key is the address of the function and data is the function name
            $map_table{ $1 } = $2;
        }
    }
    # Close map file
    close( $fin );
    # Return a reference to the map table built
    return \%map_table;
}

# builds the stack analyzer script. This script is named
# stack_analyzer_module_name.sc
# and it will be executed by simsc100 to produce the log file
sub build_stack_analyzer
{
    my $f;
    my $module = shift; # Get the first parameter (module name)
    my $function = shift; # Get the second parameter (function name)
    my $num_frames = shift; # Get the third parameter (number of frames)

    open ($f, ">stack_analyzer_". $module . ".sc") || die("Cannot create
    stack analyzer script");
```

Appendix A

```
print( $f "display off\n");
print( $f "break off\n");
print( $f "output off\n");
print( $f "input off\n\n");
# display esp as unsigned decimal
print( $f "radix u esp\n");
print( $f "reset d m1\n\n");
# quit on errors (bad function name, for example)
print( $f "quit e\n");

print( $f "load ".$module.".eld\n\n");
# count frames
if ($num_frames > 0)
{
    print( $f "break #1 _".$function." i1\n");
}
# execute frame_start script when entering the function
print( $f "break #2 _".$function." x
stack_analyzer_frame_start.sc\n");
# stop after num_frames frames
if ($num_frames > 0)
{
    print( $f "break #4 cnt1>=".($num_frames+1)."\n");
}
# display modifications of esp
print( $f "break #5 w esp s\n");
# disable breakpoint 5
print( $f "break #5 d\n");
# stop at end of program
print( $f "break #6 stop\n\n");
# set log file
print( $f "log s stack_analyzer_.$module..log -o\n");
# start simulation
print( $f "go\n");
# only breakpoint 4 or 6 can get us here
print( $f "quit\n");

close( $f );
}

=head1
The script parses the log file generated by the stack_analyzer simulator
script.

The output of this script are the maximum values for the stack size of the
analyzed
function and the stack trace.

The parameters received by this script represent the name of the .eld
file, the name
of the function and (optional) the number of frames to analyze
=cut

if ($#ARGV < 1)
{
    die("Syntax: ".$0." program_name function_name
[number_of_frames]\n");
}
```

```

# Get the name of analyzed module
my $module=<$ARGV[0]>;
# Get the name of analyzed function
my $tested_function=<$ARGV[1]>;
# Get the number of frames
my $num_frames=<$ARGV[2]>

if ($num_frames eq "")
{
# run to the end of program
    $num_frames = 0;
}

# build the stack analyzer script
build_stack_analyzer($module, $tested_function, $num_frames);

my $fin;

open( my $report_file,>"stack_analysis_" . $module . ".txt" ) || die(
"Cannot create report file!!!!");

print($report_file "\nStatistics made for $module :\n\n");

# Run the module tester to log the stack evolution
system("simsc100 stack_analyzer_".\$module.".sc > /dev/null") == 0
|| die ("Error while running simulator - please check the
parameters again\n");

# Open the stack log file of the module analyzed
open( $fin , "stack_analyzer_".\$module.".log" ) || die( "Can't open log
file : $!\n" );

my $stack_size = 0x0;
my $stack_base = 0xffffffff;
my $stack_top = 0xffffffff;

# This array will store the function call stack (pc values and not
function names)
my @functions;

# Parse the log file
# The stack pointer is esp. Typical display line for esp looks like:
#           esp={00000164264}

my $max_stack_line;
my $max_stack_start_line;
my $stack_start_line;
my $current_frame = 0;
my $max_frame;

# First, keep the first value of the stack pointer in the $stack_base
# The first occurrence of the stack pointer after a "display" line should
be at the enterance
# of the tested function. Then find the maximum of the other values =>
$stack_top

while( <$fin> )
{
# a line containing just "display" marks the beginning of the function
    if( /\s*display\s*\$/ )
    {
# memorize the start of frame
        $stack_start_line = tell( $fin );

```

```

# update number of the current frame
    $current_frame = $current_frame + 1;
# next line contains the value of esp
    $_ = <$fin>;
    /\s*esp=\{0*([0-9a-fA-F]+)\}\s*/;
    $stack_base = $1;
    $stack_base -= 8;
# next line contains the value of pc
    $_ = <$fin>;
    /^p:\$\{([0-9a-fA-F]{8})\}/;
# remember stack start for the current frame
}
elsif( /\s*esp=\{0*([0-9a-fA-F]+)\}\s*\$/ )
{
# this line contains the value of esp
    if( $1 - $stack_base > $stack_size )
    {
        $stack_size = $1 - $stack_base;
        $stack_top = $1;
# next line contains the value of pc
        $_ = <$fin>;
        /^p:\$\{([0-9a-fA-F]{8})\}/;
# Store the next line in file where the maximum stack pointer appears
        $max_stack_line = tell( $fin );
        $max_stack_start_line = $stack_start_line;
# store function name
        $functions[0] = "0x" . $1;
# store maximum stack frame number
        $max_frame = $current_frame;
    }
}
}

# Output stack dimension
print( $report_file "Maximum stack size for ".$tested_function." is ".$
$stack_size." (in frame ".$max_frame.") with the following call stack:\n"
);

# Jump to the line that follows the line that contains the maximum stack
pointer
seek( $fin , $max_stack_line , 0);

my $function= 1;

# Parse log file to find where the stack pointer decreases and store the
value of program counter
# A function can appear more than one time in the array

while( <$fin> )
{
    if ( /\s*esp=\{0*([0-9a-fA-F]+)\}\s*/ )
    {
        if( $1 < $stack_top )
        {
            $stack_top = $1;
            $_ = <$fin>;
            /^p:\$\{([0-9a-fA-F]{8})\}/;
            $functions[ $function++ ] = "0x" . $1;
        }
    }
}

```

```

my $function_name0="";
my $function_name1;
my $map_table = get_map_table( $module );

# Iterate the function array to search the function name corresponding to
each address
foreach $function ( @functions )
{
    # For each address iterate the map table
    foreach my $function_address ( sort keys %$map_table )
    {
        # If the current function has a lower address store its name.
        # Otherwise quit loop because the function name was identified and is
        stored in $function_name1
        if( hex( $function ) >= hex( $function_address ) )
        {
            $function_name1 = $$map_table{ $function_address };
        }
        else
        {
            last;
        }
    }
    # If the name of previous function differs from the current one display
    the current function name
    unless( $function_name0 eq $function_name1 )
    {
        print( $report_file $function_name1 . "\n" );
        $function_name0 = $function_name1;
    }
    # If tested_function is reached, quit
    if( $function_name1 eq $tested_function)
    {
        last;
    }
}

# Close the report file
close( $report_file );

# create trace file for the frame that produced the maximum stack

open( my $trace_file,>"stack_trace_". $module . ".txt" ) || die( "Cannot
create trace file!!!" );

# Jump to the beginning of the stack trace
seek( $fin , $max_stack_start_line , 0);
# read base of stack
$_ = <$fin>;
/\s*esp=\{0*([0-9a-fA-F]+)\}\s*/;
$stack_base = $1;
$stack_base -= 8;

my $current_size = 0;
$function_name0 = $tested_function;
$function_name1 = "unknown";
$map_table = get_map_table( $module );

```

```

while( <$fin> )
{
    if ( /\s*esp=\{0*([0-9a-fA-F]+)\}\s*/ )
    {
        $stack_top = $1;
    # Read PC value
        $_ = <$fin>;
        /^p:\$( [0-9a-fA-F]{8})/;
        $function = $1;

    # For each address iterate the map table
        foreach my $function_address ( sort keys %$map_table )
        {
    # If the current function has a lower address store its name.
    # Otherwise quit loop because the function name was identified and is
    stored in $function_name1
            if( hex( $function ) >= hex( $function_address ) )
            {
                $function_name1 = $$map_table{ $function_address };
            }
            else
            {
                last;
            }
        }
    # eliminate multiple successive apparitions of the same function
        if ( $function_name1 eq $function_name0 )
        {
            if (( $stack_top - $stack_base ) > $current_size)
            {
    # store maximum value of stack for the function
                $current_size = ( $stack_top - $stack_base );
            }
        }
        else
        {
            print($trace_file $current_size."\t".$function_name0."\n");
            $function_name0 = $function_name1;
            $current_size = ( $stack_top - $stack_base );
        }
    }
    elsif ( /\s*Break \#3.*$/ )
    {
        last;
    }
}
# print last record
print($trace_file $current_size."\t".$function_name0."\n");
close( $fin );
close( $trace_file );

```

Example 10. stack_analyzer_frame_start.sc

```

break #5 e
change cnt2 esp
break #3 esp<cnt2 x stack_analyzer_frame_end.sc
display on esp
display
go

```

Example 11. stack_analyzer_frame_end.sc

```
break #5 d
display off esp
break #3 off
go
```

NOTES:

NOTES:

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